AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 111:333–354 (2000)

Sex Differences in Activity-Related Osseous Change in the Spine and the Gendered Division of Labor at Ensay and Wharram Percy, UK

JOANNA R. SOFAER DEREVENSKI*
Department of Archaeology, Fitzwilliam College, University of Cambridge, Cambridge CB3 0DZ, UK

KEY WORDS lifestyle; gender; spine; osseous modification

ABSTRACT Sex differences in the distribution of vertebral degenerative and plastic change were examined and compared within and between samples of 51 individuals from the historically and ethnographically documented 16th–19th century site of Ensay, the Outer Hebrides, and 59 individuals from the medieval site of Wharram Percy, the Yorkshire Wolds. Both populations have a known gendered division of labor between males and females and known activity-related stresses on the spine. Osseous changes normally associated with degenerative joint disease (osteoarthritis) of the apophyseal facets and osteophytosis of the vertebral bodies were scored and reported separately. Inter- and intrasite differences were found in the frequency and distribution of osseous change down the spine. Overall, the Ensay sample was more highly stressed than that from Wharram Percy. Furthermore, differences between males and females at Ensay could be identified as relating to different types of activities. Distinctions between males and females at Wharram Percy were less marked, suggesting broadly similar lifestyles. These results accorded with expectations regarding contrasting levels of activity-related stress at the two sites and the division of labor between males and females. In particular, the prevalence and distribution of facet remodeling, facet sclerosis/eburnation, and osteophytosis in Ensay females could be related to load-bearing using creels (a form of basket), which disrupted "normal" patterns of osseous change along the spine. Importantly, morphologically distinct osseous modifications recorded on the apophyseal facets produced dissimilar distributions, suggesting that they may have different etiologies. These results highlight the need for a high degree of discrimination in recording, analyzing, and exploring activity-related osseous change. Am J Phys Anthropol 111:333–354, 2000. © 2000 Wiley-Liss, Inc.

Examinations of the manifestation of activity-related stress on the spine in archaeological populations have contrasted samples thought to have different lifestyles and culturally patterned activities (e.g., Stewart, 1947; Wells, 1964; Edynak, 1976; Jurmain, 1977, 1980, 1990; Bridges, 1991), or studied populations from a variety of prehistoric and historic periods (e.g., Chapman, 1972; Angel, 1979; Merbs, 1983; Atkinson, 1985; Bennike, 1985; Walker and Hollimon, 1989; Bridges, 1994; Kramar et al., 1990; Knüsel et al., 1997; Lovell, 1994). These studies have had varying success in identifying activity-related skeletal change. Controversy exists regarding the extent to which it is

Grant sponsor: British Academy.

*Correspondence to: Joanna R. Sofaer Derevenski, Department of Archaeology, Fitzwilliam College, University of Cambridge, Downing St., Cambridge CB2 3DZ, UK. E-mail: jrs35@cam.ac.uk

Received 3 December 1998; accepted 14 September 1999.

possible to reconstruct past lifestyles and the degree of precision with which it is possible to identify activity-markers in skeletal material (cf. Jurmain, 1990; Knüsel et al., 1997; Rogers and Waldron, 1995). Relatively few osteological studies have looked at ethnographically well-documented groups with known stresses (as opposed to individuals with documented life histories), and even fewer (e.g., Merbs, 1983) have discussed populations with known sex differences in the participation of stressful activities. Activity-related mechanical stress is often described anecdotally, and there is a need to accumulate baseline data on the impact of known activities on the skeleton by examining historically and ethnographically documented populations where possible.

This paper examines and compares the distribution of degenerative and plastic change in the vertebral apophyseal facets and osteophytosis of the vertebral bodies in two historically and ethnographically documented samples: the 16th–19th century site of Ensay, the Outer Hebrides, and the medieval site of Wharram Percy, the Yorkshire Wolds. The gendered division of labor is well-understood at both sites. Known sex differences in activity patterns at the two sites can therefore be explored through the distribution of osseous change in the spine. The use of a comparative study also enables the examination of whether skeletal differences are activity-related rather than a function of biological sex differences between males and females.

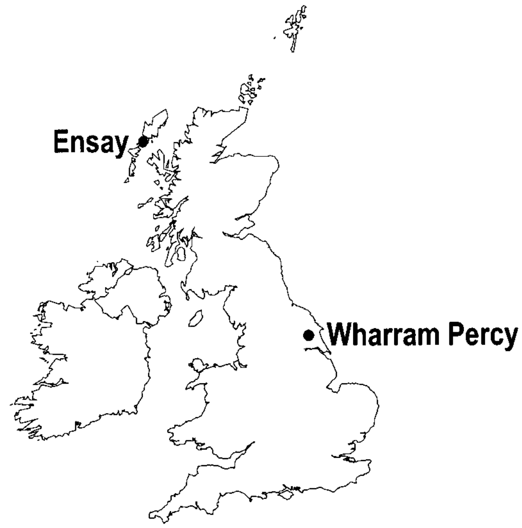

Fig. 1. Map of the UK, showing sites referred to in the text.

ENSAY AND WHARRAM PERCY: ETHNOGRAPHIC AND HISTORICAL BACKGROUND

Ensay

The island of Ensay is located in the Sound of Harris, Outer Hebrides (Fig. 1). The skeletal remains examined in this study come from the cemetery, which is located close to the northwest shore of the island in an area covered largely by sand dunes. It was excavated by Prof. Miles, who initiated systematic recovery of the remains in the years 1966 and 1967 (Miles, 1989, and personal communication). He also regularly recovered interments located just below surface level or exposed by the severe wind erosion at the site in almost every subsequent year until 1993. Since 1966, the remains of over 450 individuals have been recovered from the cemetery on Ensay. Despite persistent wind erosion no new burials have been exposed since 1993, suggesting that the majority of burials have now been removed. Although many of the graves were originally marked by uninscribed upright slabs and boulders, a series of radiocarbon dates, stratigraphical information, and historical records relating to the latest burials enable the remains to be dated (Miles, 1989, 1996). The interments in the cemetery date from ca.1500 AD, when a small chapel was built on the site, until the late 19th century (Miles, 1989, 1996).

The Western Isles were somewhat isolated from the rest of Britain, and the island communities remained relatively unaffected by outside influences until the beginning of this century (MacGregor, 1952; Macdonald, 1978). Descriptions of the island and its inhabitants in statistical accounts and the records of the MacLeod of Harris, as well as by visitors to the island, indicate that the self-sufficient crofting lifestyle of the people of Ensay remained relatively unchanged throughout the period of interment in the cemetery on the island, from the first records in the 16th century until the indig-

enous population left in about 1875 (Martin, 1703; Sinclair, 1794; Miles, 1989).

Gender roles are well-documented. Observations on the gendered division of labor in the old and new statistical accounts (1796 and 1833) are very similar to those described by visitors and residents on the Isles in the beginning and middle of this century (MacGregor, 1952; Macdonald, 1978). Gender roles were divided according to biological sex, with severe social penalties for transgression. Women were responsible for household and domestic tasks and for the majority of the heavy lifting, in particular the transport of peats for fuel and wet seaweed for fertilizer (Cameron, 1986). The carrying of such loads was done using creels, i.e., large baskets supported by a woven strap across the breastbone and around the shoulders, with the weight resting on a "dronnag" or creel pad just above the pelvis. These arrangements for the carrying of creels resulted in a characteristic posture during this activity (Fig. 2). The weight of a creel full of peats is approximately 80 lb (Murray, 1966) or 36 kg.

Men were responsible for most of the outdoor agricultural work, especially digging, rope making, bird hunting, and fishing, but did not generally participate in heavy lifting work. Nonetheless, both men and women were physically stressed from an early age as the rocky and steep terrain did not permit the frequent use of horses or ponies and carts, and both agricultural and carrying activities were done manually.

Wharram Percy

Wharram Percy is one of the best-known and most extensively investigated deserted medieval villages in Britain. It is located near the northwest scarp of the North Yorkshire Wolds (Fig. 1). The large quantity of medieval ridge-and-furrow visible in the modern landscape testifies to the predominantly agricultural economy of the settlement.

The skeletal remains examined in this study come from the churchyard of St. Martin. The earliest documentary evidence for the church comes from the annals of Meaux Abbey and dates from 1210–1220 (Bell and Beresford, 1987), although a church is thought to have stood on this site from the middle of the 10th century (Bell and Beresford, 1987). The church was in almost continuous use until 1949 and was finally abandoned in 1953. The last burial took place in 1906. Excavations at the church began in 1962, with the church and part of the churchyard excavated between 1962–1974. Part of the southeast quadrant was re-excavated in 1979.

A total of over 1,000 individuals was excavated from the interior of the church and the surrounding churchyard. Although the majority of the interments date from the medieval period, they are thought to reflect all stages of the use of the church from Anglo-Saxon to modern. The majority of medieval interments lacked headstones, and phases in the formation of the cemetery have been determined from the horizontal stratigraphy, styles of coffin fittings, and a series of human bone radiocarbon dates (Rahtz and Watts, 1983; Beresford and Hurst, 1990; Mays, personal communication). In order to ensure that all individuals examined were subject to the same gender rules, only those interments thought to be medieval in date were examined. These yielded radiocarbon dates ranging from the 10th–16th centuries A.D. (Mays, personal communication). No burials from inside the church were studied, as these may be high-status burials of individuals subject to different class-related gender restrictions and hence different levels of activity-related skeletal stress. The entire sample studied therefore came from the churchyard and is thought to be of ordinary peasants.

In contrast to the gendered division of labor on Ensay, in medieval rural communities such as Wharram Percy, men were responsible for the majority of heavy lifting and frequently used ox- or horse-drawn ploughs and carts to aid them in their labor. Furthermore, although labor in the medieval countryside was divided between the sexes, it was also subject to great variability; tasks were gender-associated and prohibitions were placed on men carrying out female tasks in the domestic arena, but the gendered division of labor outside the home was far more fluid (Bennett, 1987). Although many tasks were loosely associated with

Fig. 2. Woman carrying a creel of peats in the Western Isles (photograph, R. Smith & Sons; from Macdonald, 1978).

either men or women, few were actually proscribed for one sex (Bennett, 1987).

In medieval rural communities, women's work was primarily concerned with the domestic sphere, watching children, cleaning the house, preparing meals, brewing, baking, gardening, caring for poultry and dairy animals, making butter and cheese, and working wool and flax into cloth. Men tended to be responsible for much of the heavier work that took them away from the domestic croft, such as ploughing fields, carting goods, felling trees, and herding animals. When William Langland described the working lives of impoverished peasants in *Piers Plowman*, he depicted the husband as ploughman and the wife as not only helping the husband by goading the ox, but also working around the croft, caring for children, carding, combing, spinning, laying rushes, and preparing food (Bennett, 1987). However, documents such as the York Cause papers show that women also engaged in a variety of agricultural tasks and often joined men in the fields as planters, weeders, reapers, and gleaners (Bennett, 1987; Goldberg, 1992). The kitchener's accounts for Selby Abbey record the wages of women for washing and shearing sheep (Goldberg, 1992). Records of prosecutions under the Statute of Labourers and manorial account roles show that bailiffs sometimes hired women to do work normally assigned to men (e.g., ploughing), and men were similarly employed for traditionally female jobs such as dairying (Bennett, 1987).

The historically and ethnographically documented differences in activity patterns, both between sites and between the sexes, at Ensay and Wharram Percy relate primarily to qualitative and quantitative differences in loading as part of the gendered division of labor. Activities such as repeated heavy lifting or digging subject the spine to fatigue compressive loading (Tyrrell et al., 1985). Hence this may be the anatomical location most likely to reveal the impact of differences in gendered activities. The need to carry and transport everything by hand at Ensay suggests that overall, Ensay individuals of both sexes would display greater indications of activity-related stress on the skeleton than those from Wharram Percy. In terms of intrapopulation differences, it may be expected that the gendered division of labor on Ensay would result in a higher level of activity (loading)-related stress on the skeleton in Ensay females than males. At Wharram Percy it may be expected that males show a slightly higher level of activity (loading)-related stress than females. However, the flexibility allowed in the medieval gendered division of labor for peasants means that both men and women at Wharram Percy may be more similar in their evidence for activity-related stress than men and women at Ensay.

MATERIALS AND METHODS

The majority of research on activity-related osseous change in the spine has concentrated on the frequency and distribution of vertebral osteophytosis (OP) and osteoarthritis (OA), also known as degenerative joint disease (DJD). Plastic change (bone remodeling) of the apophyseal facets has been subject to less intensive study than degenerative lesions, and has rarely been a focus of attention. This is somewhat surprising, given that bone remodeling is a skeletal response to applied stresses in order to maintain integrity in support and movement (Rubin et al., 1990). Wolff's law of transformation states that "the form of the bone being given, the bone elements place or displace themselves in the direction of the functional pressure and increase or decrease their mass to reflect the amount of functional pressure" (Kennedy, 1989, p. 134). Barnett (1961) found that enforced changes in the movement of animals led to bone deformation. Osseous remodeling might therefore be a very good indicator of skeletal response to repeated activity-induced stress in humans (Kennedy, 1989), and in some cases its origin might be easier to relate to mechanical stress than the combination of observations involved in the identification of OA.

Buttresses of bone on the vertebral facets were first described by Fisher (1929), but have since received little attention in the literature. Mechanically induced extension of the facet onto the lamina was recognized by Shore (1935), and in recent years remodeling of the facet surface has occasionally

been observed (Farfan, 1973; Miles, 1989; Kramar et al., 1990; Molleson, 1994; Knüsel et al., 1997). Yet there appears to be little systematic description of this type of plastic change. Remodeling of the articular facets can be regarded as a response to mechanical slipping and shearing following disc compression or collapse, when the articular facets become responsible for increased weight-bearing. In such cases, the inferior and superior facets of the apophyseal joint become buttressed on the body margin of the facet, and there is a convincing congruity between the shapes of the surfaces, suggesting that the function was continuing and that the surfaces had been shaped by the forces they were subjected to. An increase in size of the articular facets is a response to use. It is "therefore a continuation of the first stage of life and must be distinguished from the decline or degeneration that is usually thought to be the first stage or precursor of OA" (Miles, no date, p. 18). Analogous forms of bone remodeling have been reported in the acromio-clavicular joint (Miles, 1996) and as squatting facets of the distal tibia (Molleson, 1989; Trinkaus, 1975).

Ease of identification and scoring has led many palaeopathologists to focus on the marginal lipping of the vertebral bodies which characterizes vertebral osteophytosis (Stewart, 1958; Chapman, 1968, 1972; Swedborg, 1974; Pfeiffer, 1977). Osteoarthritis refers to the degenerative changes seen in the synovial joints (apophyseal joints in the spine), which are characterized by focal cartilage loss with subchondral bone reaction and mild synovitis (Lovell, 1994).

However, there is "a great deal of dissension on even what constitutes osteoarthritis" (Bridges, 1993, p. 294) and hence its precise etiology, although the role of mechanical stress factors in the initiation of degenerative changes and in hastening the process of natural degeneration has often been emphasised (Goranov et al., 1983; Jurmain, 1990). Some of this confusion may result from differences between clinical observations of the condition based on patient reports of pain and swelling of the joints and observations on dry bones. Radiological studies typically under-represent joint changes when compared to autopsy and archaeological studies, since slight and moderate changes can be seen on dry bone but do not usually appear radiologically (Lovell, 1994).

Pitting and eburnation of the facet joint surfaces have been considered pathognomonic for osteoarthritis by the majority of researchers. They are thought to represent the cartilage deterioration that is a histological and radiographic sign of the condition (Ortner and Putschar, 1981; Currey, 1986; Rogers et al., 1987; Schumacher, 1988), although Rothschild (1997) recently argued that porosity has no clinical correlation with osteoarthritis.

When the subchondral plate is penetrated and in part destroyed, the impingement of bone against bone can produce thickening of the subchondral plate by bone formation either before it has been penetrated or after, so that the bone becomes sclerotic. If wear occurs between the surfaces, they may become polished or eburnated (Miles, 1996). In the absence of eburnation, Waldron (1991) suggested that the presence of any two of the following factors can be used to classify a joint as osteoarthritic: new bone around the joint margin, new bone on the joint surface, pitting on the joint surface, or deformation of the normal joint. Rogers and Waldron (1995) suggested that the formation of osteophytes alone should not be taken as evidence of osteoarthritis.

This practice is contrary to that of other workers in the field, who have not usually defined deformation of the joint contour as an element of OA and who consider osteophytes a manifestation of the osteoarthritis process, reflecting the interaction of aging processes and mechanical stress (Lovell, 1994). Marginal lipping and other changes to the apophyseal joints develop in response to either abnormal mechanical demands on normal cartilage or normal mechanical demands on abnormal (already damaged) cartilage (Howell, 1989; Lovell, 1994; Schaffler and Radin, 1992). Radin et al. (1980) demonstrated that destruction of cartilage is caused by higher than normal levels of shear stress created by a stiffness gradient in the cartilage or subchondral bone. This stiffness gradient may be caused by the healing of an excessive number of microfractures in the subchondral bone, which can result from

TABLE 1. Statistical comparison of age at death distributions in the Ensay and Wharram Percy samples ($P \leq 0.05$)

	F	*P*	*t*-value	d.f.	Two-tailed significance
Difference between sites					
Males	2.396	0.128	0.57	52	0.573
Females	1.991	0.164	1.62	54	0.111
Sex Difference within site					
Ensay	0.048	0.828	−0.31	49	0.759
Wharram Percy	0.018	0.894	0.67	57	0.507

TABLE 2. Number of individuals from Ensay and Wharram Percy with complete segments of the spine

	Number of complete segments			
Segment of spine	Ensay males (N = 23)	Ensay females (N = 28)	Wharram Percy males (N = 31)	Wharram Percy females (N = 28)
C1–C7	20	25	31	28
T1–T6	22	27	31	28
T7–T12	22	27	31	28
L1–sacrum	20	25	31	28

apparently "trivial" trauma (Radin et al., 1980).

Despite recent attempts to question the etiology of degenerative change and perceptions of OA as a systemic disorder increasing with age (Maat et al., 1995), the evidence for degenerative change in younger individuals following repeated mechanical loads placed upon the joints is widely accepted (Radin et al., 1972; Peyron, 1986; Bridges, 1991). Soft-tissue degeneration occurs in the spine in all individuals by age 30 years, but is rare subchondrally before that age (Schmorl and Junghanns, 1971).

In order to separate the effects of activity-related change from those caused by natural degeneration, in this study only the vertebral columns of sexed individuals of estimated age 18–45 years were examined. Application of the F-test for equality of variances and *t*-test for equal variances in a normally distributed variable indicated no significant differences between the estimated age distributions of the samples (Table 1).

All adult individuals from Ensay had previously been aged and sexed by Miles (1989, 1996). All adult individuals from Wharram Percy had previously been aged and sexed by Mays (1996). At both sites, sex was determined using standard osteological criteria (Brothwell, 1981; Stewart, 1976). Age at death was estimated on the basis of dental wear and calibrated using analogous methodologies (Miles, 1962, 1963; Kieser et al., 1983; Brothwell, 1981). Dental wear has been shown to be a reliable method of determining age at death in a variety of living and dead populations (Mays, 1996). The author found no disagreement with the original determinations, confirming these estimates. Hence the age and sex determinations of Miles and Mays were used in the analysis.

A total of 51 individuals with complete spines or complete segments of the spine (C1–C7, T1–T6, T7–T12, and L1–sacrum) was examined from Ensay, of whom 28 were female and 23 male. A total of 59 individuals with complete spines or segments was examined from Wharram Percy, of whom 28 were female and 31 male (Table 2). The division of the spine into segments not only reflects the morphology of the vertebrae but also the curvature of the spine. The degree of preservation at both sites was excellent. The samples represent the full number of individuals in this age range at Ensay and Wharram Percy, excluding a total of 8 individuals from both sites diagnosed as having suffered from tuberculosis (TB). Changes in the spine associated with TB (Ortner and Putscher, 1981) should be separated from those that may be activity-related.

Scoring methods

In view of the controversy regarding which observations constitute and define OA in skeletal material, each apophyseal facet was scored separately for the presence/absence and severity of facet remodeling, osteophytes, pitting, and sclerosis/eburnation. Vertebral bodies were scored for level of osteophytosis. In order to allow the maximum degree of discrimination, superior and inferior, and left and right aspects were scored separately, and mean joint scores were calculated for individual observations at each articulation.

Few pre-existing descriptions of remodeling of the apophyseal facet are available in the literature. Following initial inspection of

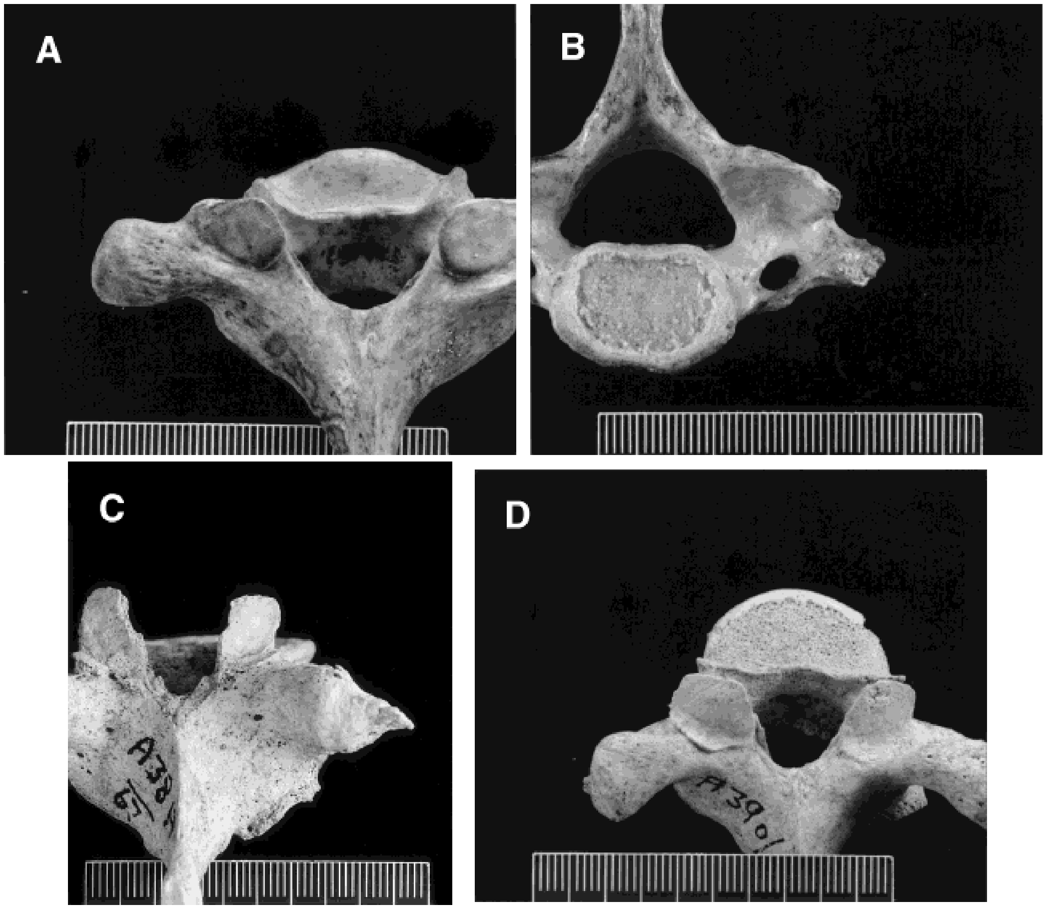

Fig. 3. Scoring and stages of facet remodeling on the apophyseal facet (photographs courtesy of the Natural History Museum, London). **A:** Normal apophyseal facet: superior aspect T1 (D35/67 Ensay). **B:** Stage 1 facet remodeling: inferior aspect C7 (A312/67 Ensay). **C:** Stage 2 facet remodeling: superior aspect T9 (A38H/67 Ensay). **D:** Stage 3 facet remodelling: superior aspect T3 (A39O/67 Ensay). Scale in mm.

the material, a new scale of observation was therefore developed by the author in order to describe this form of morphological change and distinguish it from changes caused by osteophytic growth or degenerative changes. Facet remodeling was scored on a scale of 0–3, representing a complete absence of remodeling to severe changes in facet morphology: 0 = normal superior facet with sharply defined margins. The laminal groove is clearly visible and the articular process is clearly separated from the transverse process. The margin of the inferior articular facet of the preceding vertebra does not rest on the lamina of the succeeding vertebra and is sharply defined (Fig. 3A); 1 = the inferior margin of the superior articular facet is indistinct and the facet has an increased surface area extending onto the lamina, or downwards into a deepened laminal groove. The inferior margin of the inferior articular facet of the preceding vertebra rests on the lamina of the succeeding vertebra, is rounded, and may be sclerosed or eburnated (Fig. 3B); 2 = as in 1, with the addition of a small bony shelf on the lamina of the lower vertebra supporting the inferior articular process of the preceding vertebra (Fig. 3C); and 3 = as in 2, with a larger bony shelf extending further downwards into the lamina and outwards onto the transverse process of the lower vertebra. The superior

margin of the superior articular process is bent over and rounded in an anterior direction. The inferior articular facet of the preceding vertebra has an indistinct superior margin, with extension of the facet surface towards the vertebral notch matching the shape of the superior articular facet of the succeeding vertebra in jigsaw fashion (Fig. 3D).

Osteophytes on the apophyseal facet were scored following the Säger system on a scale of 0–4, representing absence to fusion of facets (Säger, 1969), but were scored separately from other joint changes (Atkinson, 1985). In practice, the highest level of the scale was never used. Bony shelves on the lamina resulting from facet remodeling were clearly distinguishable and were not counted as osteophytes. Cases of congenital fusion of the facets, bone formers (Rogers and Waldron, 1995), or diffuse idiopathic skeletal hyperostosis (DISH) were not scored; the etiology of bone-forming and DISH are poorly understood and have not been demonstrated to be activity-related (Arriaza, 1993; Arriaza et al., 1993).

Pitting was scored on a five-point scale (0–4) relating to the size of the largest pit observed rather than the proportion of joint surface covered or number of individual pits. However, following Lovell (1994), more than 10% of the surface had to be affected to count as pitting. Pitting was scored as follows: 0 = absent; 1 = small pits <0.5 mm in diameter; 2 = medium pits 0.5–1.0 mm in diameter; 3 = large pits >1.0 mm and ≤1.5 mm in diameter; and 4 = craters >1.5 mm in diameter.

Sclerosis and eburnation are related phenomena, in that eburnation never occurs without previous sclerosis, but sclerosis may occur without subsequent eburnation (Knüsel et al., 1997; Rogers et al., 1995). They were inspected visually and, since eburnation is probably a progression from sclerosis (Rogers et al., 1987), were scored continuously: 0 = absent; 1 = sclerosis only; 2 = sclerosis with some eburnation visible on the same facet; 3 = eburnation more extensive than sclerosis on the same facet; and 4 = extreme eburnation.

Osteophytes on the vertebral body were scored according to the Säger system on a scale of 0–4, representing absence to ankylosis (Säger, 1969), but were recorded independently of other joint changes. Osteophytosis is taken to be the degree of osteophyte formation on the body edge (Atkinson, 1985). It was recorded only when arising horizontally from the margins of the vertebral body, as opposed to the vertical ossification of an enthesis (e.g., the anterior longitudinal ligament), bone formers, or DISH. Where these conditions were present, osteophytosis was not scored. Thus, in practice, the highest level of the Säger scale was never used.

In order to avoid knowledge of sex or age influencing observer recording, vertebrae were scored "blind" according to serial or site number. All vertebrae were scored by a single observer to avoid inter-observer error. Vertebrae from both samples examined at the beginning of the study were later rescored in order to check scoring consistency. A high level of agreement was achieved between the first and second sets of scores. Where poor preservation or other factors meant that any observation at a particular location could not be scored, it was recorded as "unobserved" and was not included in the total sample for frequency calculations. Minimum scores were recorded in cases of uncertainty.

The chi-square test was used to examine the existence of inter- and intrasite sex differences in the prevalence of osseous change. However, where expected values were less than or equal to 5, Fisher's exact test was applied (significant ≤ 0.05). Both tests operate on the basis of proportional presence/absence. Hence, differences in the frequency of observations can be taken into account.

RESULTS

Following Bridges (1994), the results are presented graphically as the percentage of each articulation affected, in order to highlight the distribution of each type of change down the spine. For the statistical analyses of sex differences, the spine was divided into segments reflecting not only the morphology of the vertebrae but also the curvature of the spine (C1–C7, T1–T6, T7–T12, and L1–sacrum), and the analyses were carried out in terms of the number of individuals af-

*TABLE 3. Total percentage of individuals in the Ensay and Wharram Percy samples displaying one or more affected articulations and their statistical significance between sites and within sites**

	% total affected individuals (frequency data in parentheses)				Difference between sites, males		Difference between sites, females		Sex difference within site, Ensay		Sex difference within site, Wharram Percy	
	Ensay		Wharram Percy									
Observation	Males (N = 23)	Females (N = 28)	Males (N = 31)	Females (N = 28)	χ^2	Significance	χ^2	Significance	χ^2	Significance	χ^2	Significance
Facet remodeling	83% (19)	82% (23)	81% (25)	57% (16)	0.034	1.000[1]	4.139	**0.042**	0.002	1.000[1]	3.833	**0.050**
Facet osteophytes	91% (21)	86% (24)	61% (19)	53% (15)	6.194	**0.013**	6.842	**0.009**	0.380	0.678[1]	0.359	0.549
Facet pitting	91% (21)	89% (25)	77% (24)	82% (23)	1.833	0.273[1]	0.583	0.705[1]	0.058	1.000[1]	0.203	0.653
Facet sclerosis/ eburnation	70% (16)	71% (20)	55% (17)	39% (11)	1.205	0.272	5.853	**0.016**	0.021	0.884	1.427	0.232
Osteophytosis	91% (21)	86% (24)	71% (22)	71% (20)	3.367	0.092[1]	1.697	0.193	0.380	0.678[1]	0.002	0.969

* $P \leq 0.05$. Significant values in bold type. In all cases, d.f. = 1.
[1] Where one or more of the expected frequencies is less than or equal to 5, Fisher's exact test has been used.

fected in each segment. This gives a better indication of the biomechanical effects of loading on different areas of the spine than the more frequent presentation of results based solely on vertebral morphology.

Intersite differences

Table 3 shows the total percentage of males and females from each sample with one or more articulations affected by facet remodeling, osteophytes, pitting and sclerosis/eburnation on the articular facets, and osteophytosis of the vertebral body. All changes on the articular facets and osteophytosis occur more frequently in individuals in the Ensay sample than in those of the same sex from Wharram Percy. Application of the chi-square test (all chi-square values are given in the tables) shows that these frequencies are significant between males from the two sites for the prevalence of osteophytes on the articular facets ($P = 0.013$). Significant differences between females from Ensay and Wharram Percy are found for facet remodeling ($P = 0.042$), facet osteophytes ($P = 0.009$), and sclerosis/eburnation ($P = 0.016$).

Intrasite differences

Intrasite differences between the sexes in the total percentage of individuals affected are small for all observations in the Ensay sample. None are statistically significant. In the Wharram Percy sample, only facet remodeling displays significant intrasite difference, being found in a greater total percentage of males than females ($P = 0.050$) (Table 3).

However, looking merely at sex differences in the total percentage of individuals affected can be misleading, as it hides variation in the distribution and frequency of the types of osseous change in different regions of the spine. It is therefore more useful to look at the proportion of individuals affected in each of the segments of the spine (Tables 4 and 5), and to visually inspect the distribution of change down the spine (Figs. 4–8).

Visual inspection of Figure 4 suggests that males and females from Ensay display different distributions of facet remodeling down the spine. The greatest prevalence of facet remodeling was observed in the upper thoracic region, with the most frequently affected vertebra being T1 for both sexes (Fig. 4). However, while Ensay females display a block of affected vertebrae in the upper thoracic region, in contrast to Ensay males no severely affected vertebrae are found in the lower thoracic area and almost no facet remodeling is displayed in the lower thoracic and lumbar regions. This visual impression is confirmed by statistical analysis of intrasite sex differences in the prevalence of facet remodeling (Table 4). No significant difference is found between the sexes in the cervical or upper thoracic segment. However, significant differences are found between Ensay males and females in the lower thoracic segment on both right and left sides ($P = 0.007$, left side; $P = 0.019$, right side), with more males than females affected in

*TABLE 4. Sex differences in the prevalance of osseous change in the Ensay sample and their statistical significance**

Observation	Segment of spine	Number of affected individuals, aspect				% affected individuals, aspect				χ^2, aspect		Significance	
		Left		Right		Left		Right					
		M	F	M	F	M	F	M	F	Left	Right	Left	Right
Facet remodeling	C1–C7	3	3	2	3	15	12	10	12	0.087	0.045	1.000[1]	1.000[1]
	T1–T6	14	17	17	21	64	63	77	78	0.002	0.002	0.961	0.966
	T7–T12	10	3	11	5	45	11	50	19	7.335	5.463	**0.007**	**0.019**
	L1–sacrum	4	0	3	1	20	0	15	4	5.488	1.660	**0.033**[1]	0.309[1]
Facet osteophytes	C1–C7	6	5	6	5	30	20	30	20	0.602	0.602	0.500[1]	0.500[1]
	T1–T6	12	6	11	12	55	22	50	44	5.450	0.150	**0.020**	0.698
	T7–T12	15	10	12	14	68	37	55	52	4.705	0.035	**0.030**	0.851
	L1–sacrum	9	12	7	15	45	48	35	60	0.040	2.779	0.841	0.096
Facet pitting	C1–C7	8	5	6	6	20	40	30	24	2.163	0.205	0.141	0.651
	T1–T6	16	18	16	21	73	78	73	67	0.210	0.167	0.647	0.683
	T7–T12	13	13	12	10	59	48	55	37	0.582	1.502	0.445	0.220
	L1–sacrum	3	4	3	6	15	16	15	24	0.008	0.563	1.000[1]	0.710[1]
Facet sclerosis/eburnation	C1–C7	2	2	2	2	10	8	10	8	0.055	0.055	0.815[1]	0.815[1]
	T1–T6	6	8	12	12	27	30	55	44	0.033	0.495	0.856	0.482
	T7–T12	6	1	8	3	27	4	36	11	5.499	4.440	**0.036**[1]	**0.046**[1]
	L1–sacrum	1	2	2	3	5	8	10	12	0.161	0.045	1.000[1]	1.000[1]
Osteophytosis	C1–C7	4	6	3	5	20	24	15	20	0.103	0.190	1.000[1]	0.716[1]
	T1–T6	7	5	5	7	32	19	23	26	1.160	0.067	0.282	0.796
	T7–T12	11	13	12	14	50	48	55	52	0.017	0.035	0.897	0.851
	L1–sacrum	11	22	11	21	55	88	55	84	6.188	4.549	**0.013**	**0.049**

* $P \leq 0.05$. Significant values in bold type. In all cases, d.f. = 1. M, male; F, female.
[1] Where one or more of the expected frequencies is less than or equal to 5, Fisher's exact test has been used.

*TABLE 5. Sex differences in the prevalence of osseous change in the Wharram Percy sample and their statistical significance**

Observation	Segment of spine	Number of affected individuals, aspect				% affected individuals, aspect				χ^2, aspect		Significance	
		Left		Right		Left		Right					
		M	F	M	F	M	F	M	F	Left	Right	Left	Right
Facet remodeling	C1–C7	4	1	1	1	13	4	3	4	1.652	0.005	0.356[1]	1.000[1]
	T1–T6	15	11	21	12	48	39	68	43	0.494	3.696	0.482	0.055
	T7–T12	9	2	8	4	29	7	26	14	4.647	1.205	**0.031**	0.272
	L1–sacrum	3	3	2	3	10	11	7	11	0.017	0.345	1.000[1]	0.661[1]
Facet osteophytes	C1–C7	8	7	7	3	8	25	23	11	0.005	1.472	0.943	0.306[1]
	T1–T6	4	3	4	3	13	11	13	11	0.067	0.067	1.000[1]	1.000[1]
	T7–T12	7	2	10	3	23	7	32	11	2.712	3.975	0.150[1]	**0.046**
	L1–sacrum	9	7	9	7	29	25	29	25	0.121	0.121	0.728	0.728
Facet pitting	C1–C7	10	4	6	4	32	14	19	14	2.626	0.269	0.105	0.734[1]
	T1–T6	16	11	16	15	52	39	52	54	0.901	0.023	0.343	0.880
	T7–T12	7	8	10	8	23	29	32	29	0.278	0.094	0.598	0.759
	L1–sacrum	11	9	10	12	36	32	32	43	0.073	0.707	0.787	0.401
Facet sclerosis/eburnation	C1–C7	7	6	5	4	23	21	16	14	0.011	0.039	0.915	0.844
	T1–T6	6	2	8	4	19	7	26	14	1.872	1.205	0.259[1]	0.272
	T7–T12	1	1	2	1	3	4	7	4	0.005	0.253	1.000[1]	1.000[1]
	L1–sacrum	5	5	3	6	16	18	10	21	0.031	1.572	1.000[1]	0.285[1]
Osteophytosis	C1–C7	12	8	9	8	39	29	29	29	0.675	0.002	0.411	0.969
	T1–T6	11	14	14	10	36	50	45	36	1.270	0.544	0.260	0.461
	T7–T12	15	15	16	15	48	54	52	54	0.158	0.023	0.691	0.880
	L1–sacrum	18	17	18	16	58	61	58	57	0.043	0.005	0.836	0.943

* $P \leq 0.05$. Significant values in bold type. In all cases, d.f. = 1. M, male; F, female.
[1] Where one or more of the expected frequencies is less than or equal to 5, Fisher's exact test has been used.

this region. Despite the small number of observations in the lumbar region, significantly more males than females are affected in this region on the left facet ($P = 0.033$).

In the Wharram Percy sample, females are less affected than males throughout the spine, but appear to have a similar distribution pattern (Fig. 4). Indeed, Figure 4 sug-

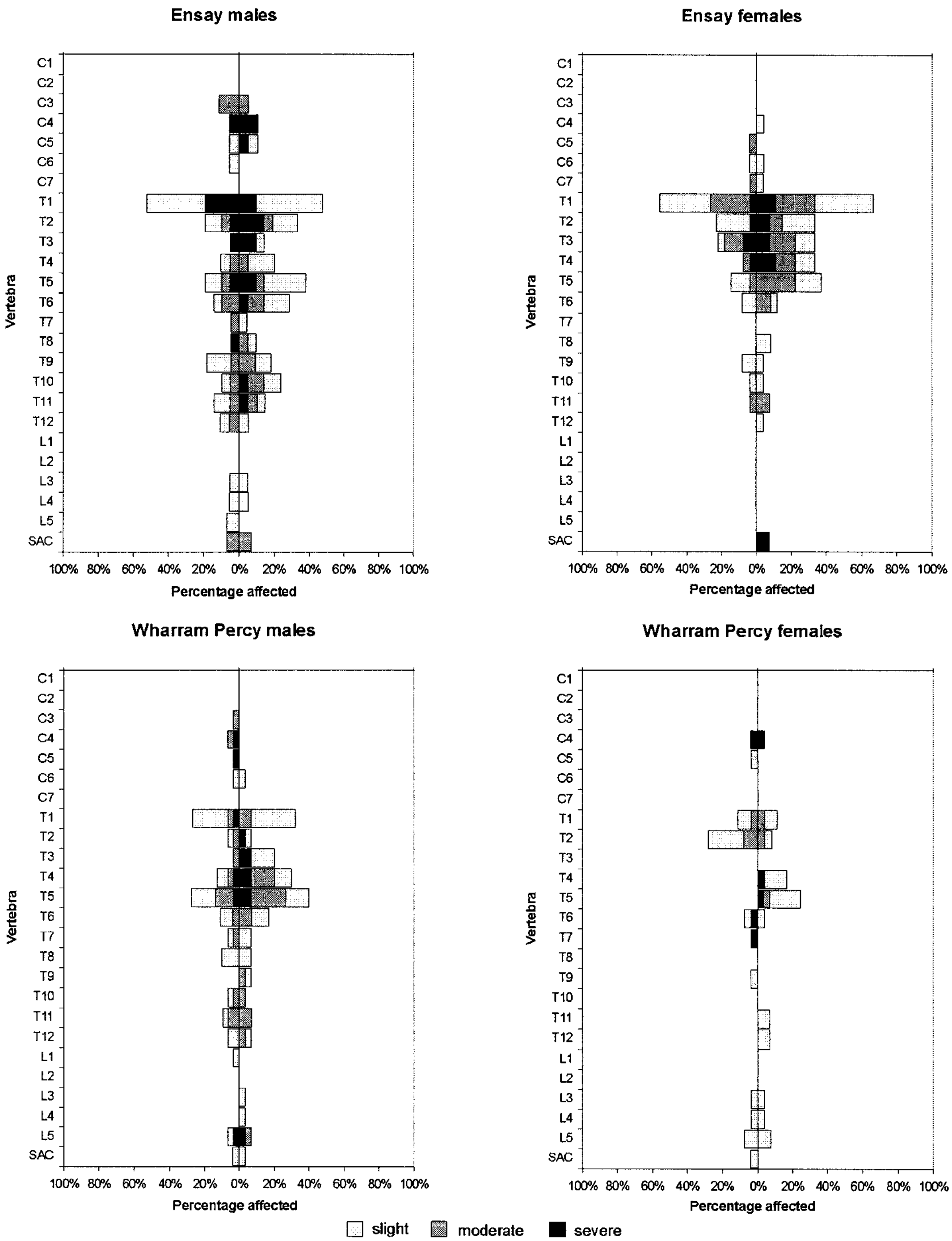

Fig. 4. Distribution of apophyseal facet remodeling along the spine.

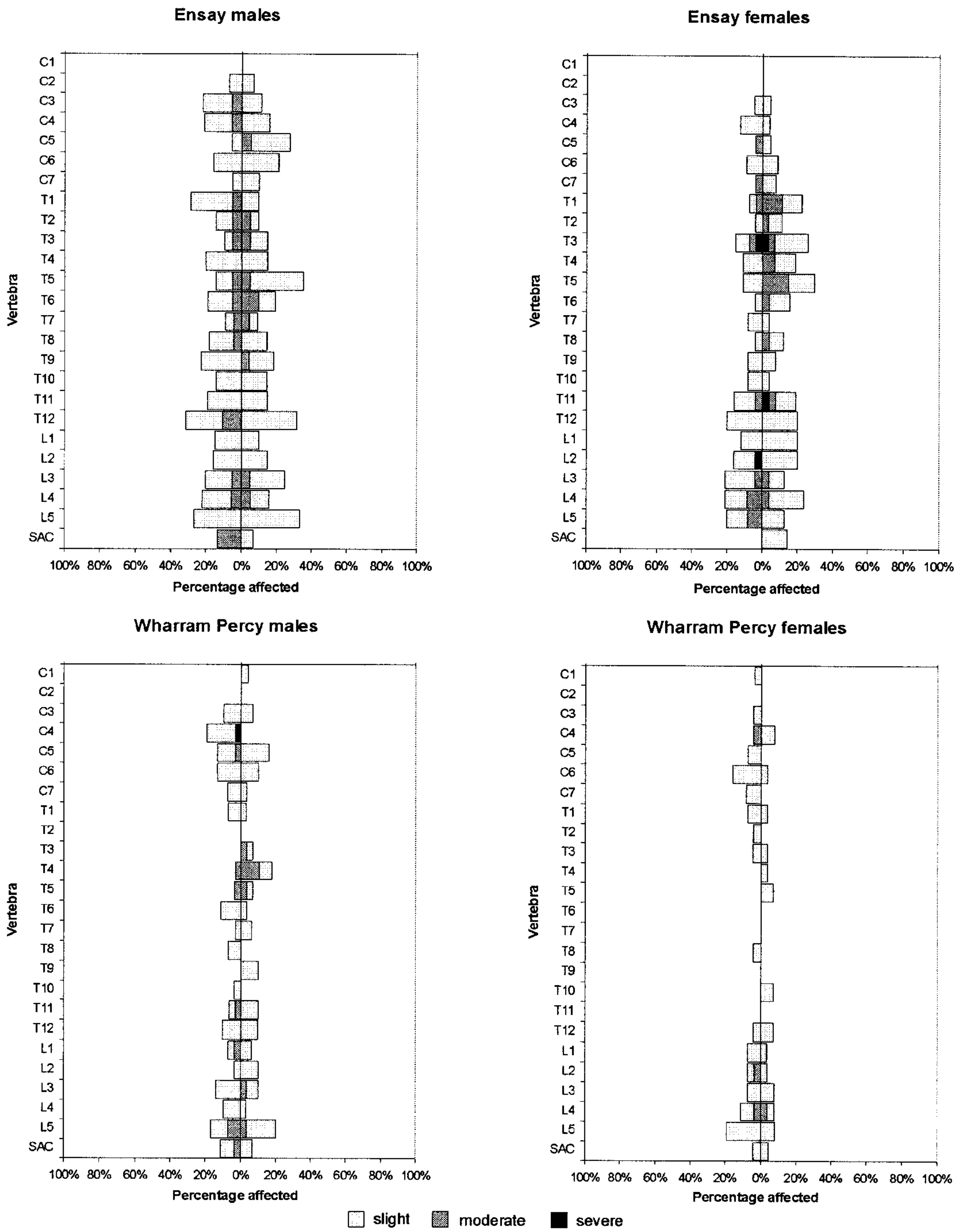

Fig. 5. Distribution of osteophytes on the apophyseal facet along the spine.

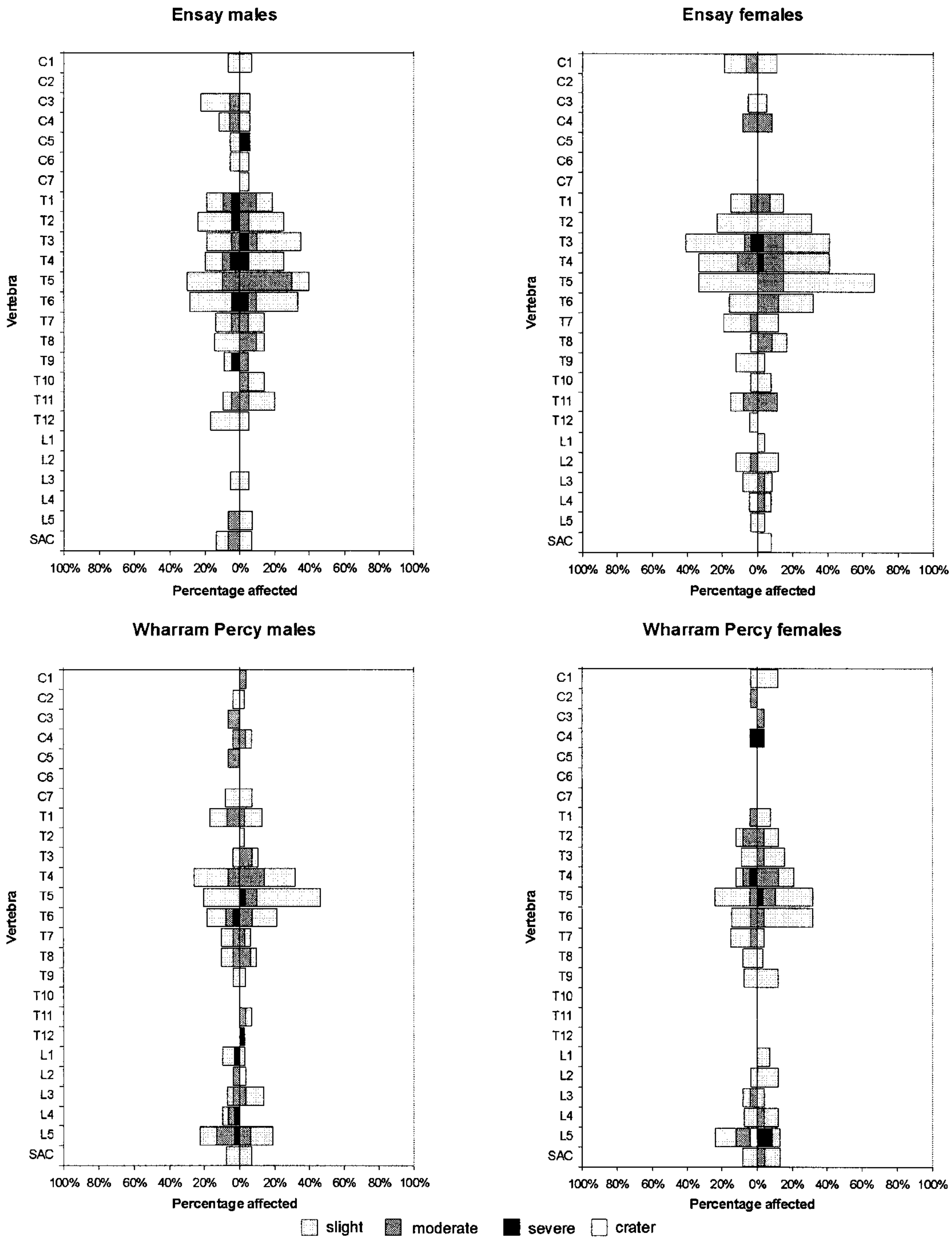

Fig. 6. Distribution of pitting on the apophyseal facet along the spine.

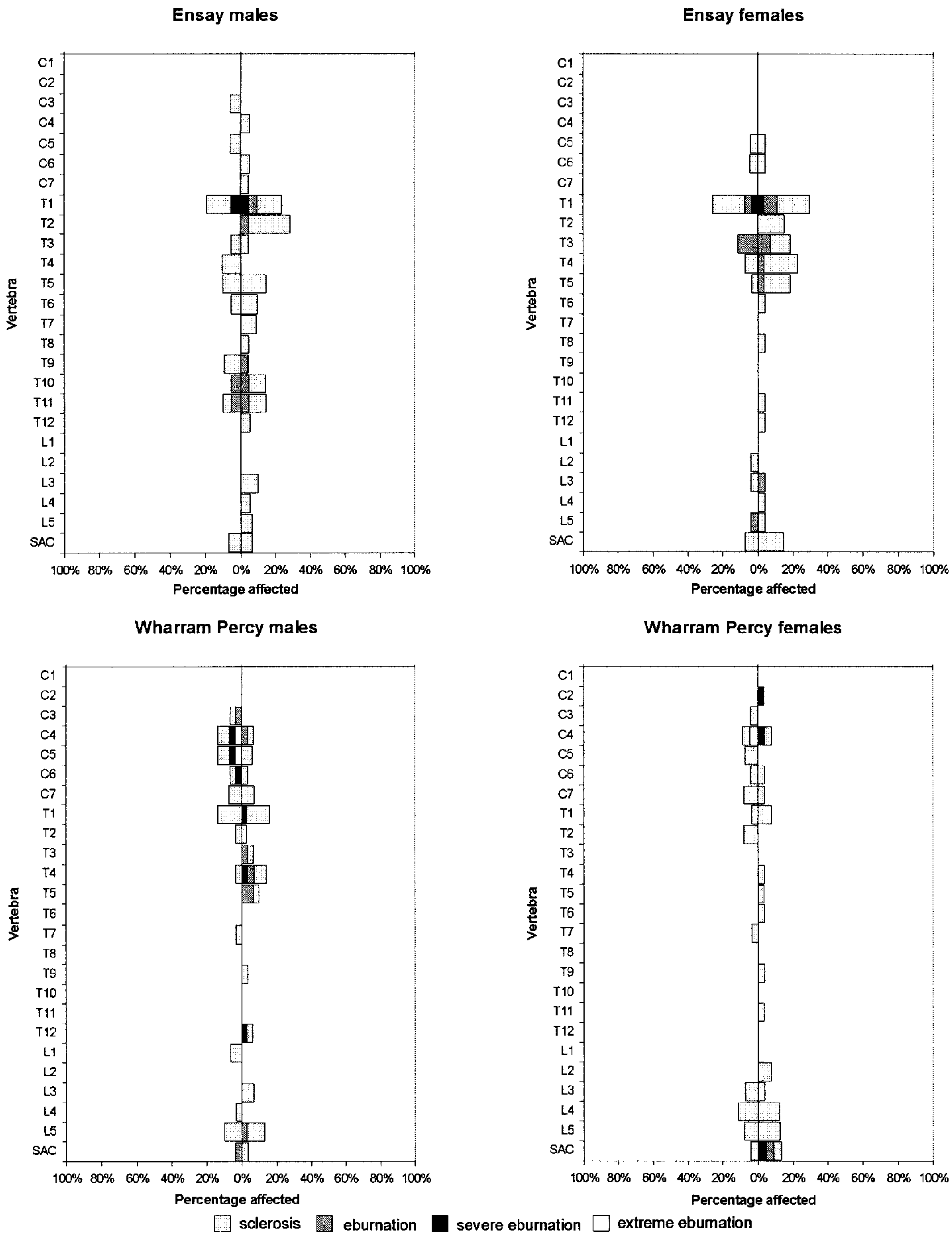

Fig. 7. Distribution of sclerosis and eburnation on the apophyseal facet along the spine.

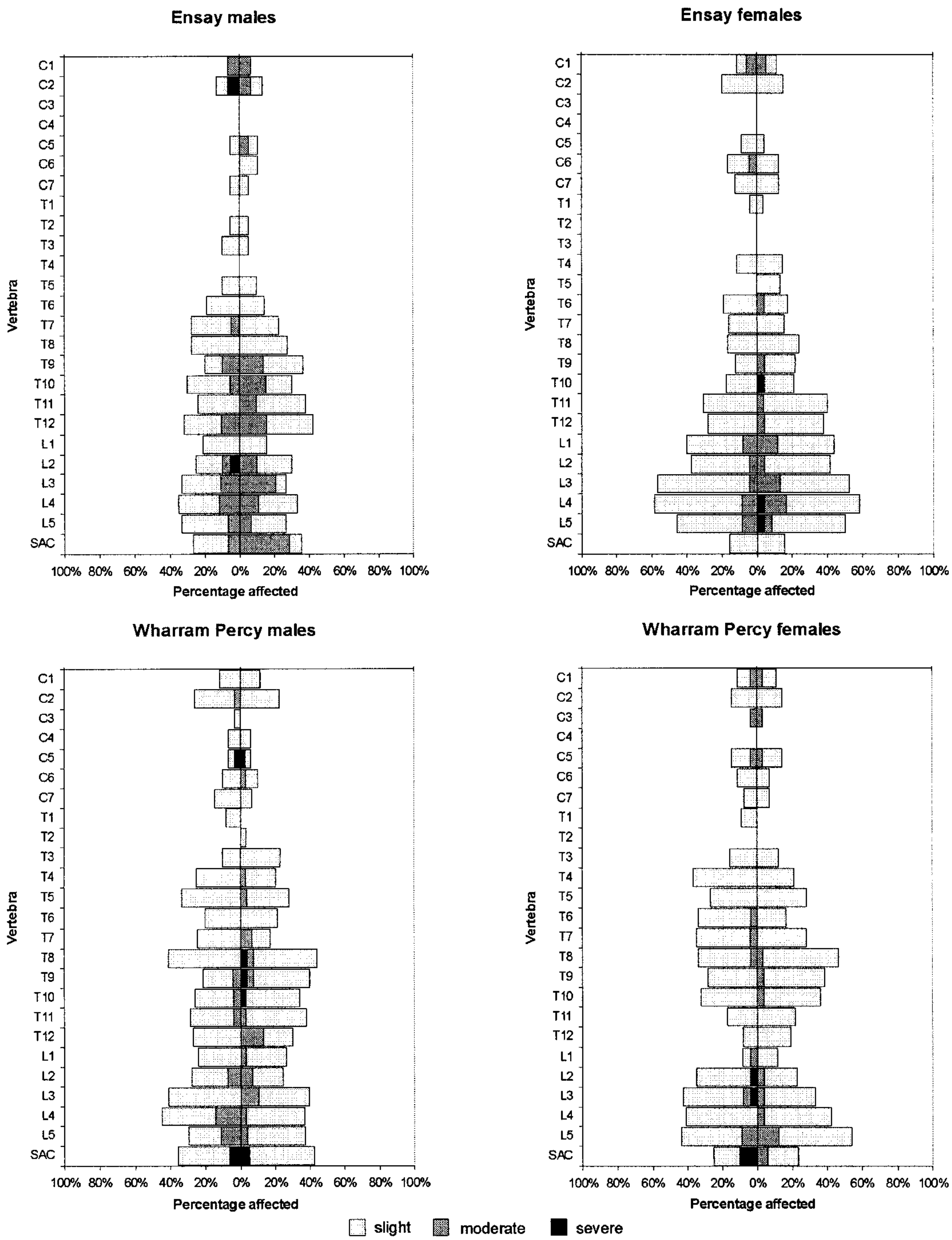

Fig. 8. Distribution of osteophytosis along the spine.

gests that Wharram Percy females are the least affected sample from both sites. The Wharram Percy sample displays sex differences on the border of significance for the prevalence of facet remodeling on the right side in the upper thoracic segment (P = 0.055) and a significant value on the left side in the lower thoracic segment (P = 0.031) (Table 5).

Figure 5 shows the distribution of osteophytes on the apophyseal facets along the spine. Only slight sex differences are noticeable within the Ensay sample. For Ensay males the distribution of osteophytes along the spine is fairly even, with no severely affected vertebrae. In females, severely affected vertebrae can be observed at T3 and T11 on the right side and T3 and L2 on the left side. The chi-square test shows that significantly more males in the upper thoracic region display osteophytes on the left facet (P = 0.020) (Table 4). In the lower thoracic region, significantly more males than females are again affected by osteophytes on the left facet (P = 0.030). There is no significant sex difference on either side in the lumbar region. Both sexes from Wharram Percy display similar distribution patterns down the spine. Nonetheless, Wharram Percy males are significantly more affected on the right side in the lower thoracic segment (P = 0.046) (Table 5).

Figure 6 reveals that both sexes from both sites show similar distributions of pitting down the spine. Application of the chi-square test indicates no significant differences between males and females in any region of the spine for either Ensay or Wharram Percy (Tables 4 and 5).

The distribution of sclerosis and eburnation along the spine for males and females at Ensay is similar to that for facet remodeling, but with lower percentage frequencies of affected articulations (Fig. 7). Despite the small number of observations, Ensay males are significantly more affected than Ensay females on both sides in the lower thoracic segment (left side, P = 0.036; right side, P = 0.046) (Table 4). Low percentage frequencies of sclerosis and eburnation were also recorded for both sexes in the Wharram Percy sample. Wharram Percy males and females display similar distributions, with extreme and severe eburnation in the cervical region. Application of the chi-square test confirms that there are no significant differences between males and females in any region of the spine in the Wharram Percy sample (Table 5).

Figure 8 reveals sex differences in the distribution of osteophytosis on the vertebral body along the spine. Ensay males display evenness in the pattern of osteophytosis in the lower half of the spine. By contrast, Ensay females show a clear progressive increase in frequency throughout the lower thoracic and lumbar segments, resulting in a "skirt-like" distribution. Ensay females are significantly more affected in the lumbar region than Ensay males (P = 0.013, left side; P = 0.049, right side) (Table 4). Wharram Percy males display an even distribution of osteophytosis in the lower half of the spine. The distribution is more uneven for Wharram Percy females. However, there are no significant sex differences in any region of the spine in the Wharram Percy sample (Table 5).

DISCUSSION

Plastic and degenerative changes of the apophyseal facets and vertebral bodies occur in the majority of individuals from both Ensay and Wharram Percy. However, as described above, the frequency of individuals of both sexes displaying such changes is higher in the Ensay sample than in that from Wharram Percy (Table 3). Thus, while factors other than purely mechanical ones may affect the prevalence of osseous change (Engel, 1968; Hollander and McCarty, 1972; Pinals, 1972; Bridges, 1991), this finding suggests that the Ensay sample was subject to a greater overall level of skeletal stress than that from Wharram Percy. This corresponds well with anthropological and historical descriptions of the different lifestyles at the two sites.

Turning to intrasite sex differences in the level of stress, the pattern becomes more complex. In the Ensay sample, the percentage of male and female individuals affected by changes on the facets and bodies is very similar. There are no statistically significant differences (Table 3). This suggests that Ensay men and women were subject to

similar overall levels of skeletal stress. However, the prevalence and distribution of osseous changes differ between males and females in different segments of the spine. Statistical analysis of the segments shows that facet remodeling (lower thoracic and lumbar segments), facet osteophytes (upper and lower thoracic segments), and facet sclerosis/eburnation (lower thoracic segment) are significantly more prevalent in males. Osteophytosis is significantly more prevalent in the lumbar segment of females (Table 4). These results suggest that the load-bearing role of Ensay women did not lead to a straightforward increase in osseous modification. Rather, the contrasting patterns of osseous change in men and women from Ensay suggest that they may have been subject to different forms of stress on the spine.

In the Wharram Percy sample, only the frequency of individuals displaying facet remodeling is significantly different, with greater prevalence in males (Table 3). The mechanically induced nature of facet remodeling suggests that this may be due to greater load-bearing by males in the Wharram Percy sample. However, both sexes display similar distribution patterns of osseous change in almost all segments of the spine. Of the 40 segment comparisons in Table 5, only two are statistically significant. This would be expected by chance, with an alpha level set at 0.05. These results conform to expectations, suggesting that both sexes at Wharram Percy were subject to broadly similar forms and levels of stress.

Variability in the distribution of osseous change within the spine

Sex differences in the distribution of osseous change down the spine in the Ensay sample can be understood by reference to the biomechanical implications of carrying creels.

In a biomechanically “normal” spine, as in Ensay males or both sexes from Wharram Percy, naturally occurring distributions of osseous change result from the curvature of the spine in an erect posture and anatomical and functional differences between vertebrae. The regions of the spine most subject to osseous change of the facets are locations most subject to stress through movements either reducing or accentuating the vertebral curvatures or transitional vertebrae. Although differences in observation and scoring techniques make it difficult to make direct comparisons, others (e.g., Knüsel et al., 1997) have found similar distribution patterns of DJD coinciding with those areas of the spine naturally subject to stress. The C7/T1 junction is particularly vulnerable. Here the vertebral column changes from being weight-bearing to increasing rotation and from anterior to posterior curvature (Knüsel et al., 1997). It is therefore likely that inferior facets may slip down onto the superior facets of adjacent vertebra at the C7/T1 junction, leading to pressure and plastic remodeling of the facets.

In a “normal” spine, the natural curvature moderates the transfer of weight down the spine. Osseous change on the vertebral bodies mirrors the vertebral curvatures. It is most severe where the curvatures are furthest away from the line of gravity and least where the vertebral column passes through the line of gravity. Osseous change is most frequent and severe in the lower half of the spine, where the load is greatest. Similar findings were reported by Bridges (1994) in relation to the prevalence of osteophytosis on the vertebral body. A number of studies have shown that patterning of OA of the apophyseal facets is quite different from, and even inverse to, that of osteophytosis of the vertebral bodies (e.g., Bridges, 1994; Knüsel et al., 1997).

Load-bearing can increase stress levels at given points down the spine. Again, differences in scoring, observation, and data presentation make it difficult to directly compare the results described above with those from research on other populations. Nonetheless, a number of studies have associated load-carrying with a peak of OA in the upper thoracic vertebrae (Shore, 1935; Stewart, 1979; Kilgore, 1984; Jurmain, 1990). In the study by Merbs (1983) of the Sadlermiut, he found the peak thoracic value on the right side at about T4/5 and at T11/12 on the left. Bridges (1994) found peaks of OA in the mid-cervical, lower thoracic, and lower lumbar regions in her Alabama sample. Lovell (1994) observed severe lesions in the cervi-

cal spine of individuals from Harappa. However, in all these cases the method of burden-carrying, whether by tumpline or on the head, is biomechanically different from that at Ensay, where creels were used.

Carrying creels distinctively modifies the normal curvature of the spine during load-bearing, changing the normal biomechanics of the spine. Miles (1989, p. 113) pointed out that the method of carrying creels supported by a strap across the breastbone and round the shoulders "would seem to place, through the first rib, maximal pressure on T1 and to a gradually diminishing extent on the vertebrae below that level." Merbs (1983) suggested that carrying using a band across the upper chest increases thoracic arthritis.

Ensay females have a block of vertebrae affected by facet remodeling and sclerosis/eburnation in the upper thoracic region, and are particularly affected at T1. However, they do not display a statistically significant increase over Ensay males in the prevalence of osseous change in this segment. Furthermore, facet osteophytes on the left side (the only statistically significant difference in the upper thoracic region) are more prevalent in males.

Nonetheless, Ensay females do display evidence of a reduction in stress on the facets in the lower half of the spine, particularly in the lower thoracic region where facet remodeling, facet osteophytes, and facet sclerosis/eburnation are significantly less prevalent. Carrying creels transforms the normal S-shape curvature of the spine into a hook. The curves of the lower thoracic and lumbar regions are straightened out. Weight is not transferred directly down the spine, but spread over the chest and upper back. This alteration in posture can be regarded as responsible for the sex differences observed in the lower thoracic segment. The straightening out of the spine means that the articular facets play very little role in weight-bearing (Adams and Hutton, 1980; Yang and King, 1984; Oliver and Middleditch, 1991). Hence, Ensay females are less affected in this region, as the facets are less subject to stress. The vertebral bodies in the lumbar region, however, continue to be stressed, as weight remains transmitted through them, but without the moderating influence of curvature. This results in a significant increase in the prevalence of osteophytosis and its characteristic "skirt-like" distribution at the base of the spine.

Carrying loads in this manner places less strain on the lower back, reducing the chances of hyperextension which might lead to fracture of vertebral arches and bodies under the weight of the creels. Instead, this abnormal posture leads to more dramatic osteophyte formation as a response, lending the spine extra added bony support.

Etiology of osseous change on the articular facets

In both the Ensay and Wharram Percy samples, each type of osseous change recorded on the articular facets shows a different distribution pattern down the spine (Figs. 4–8). Only the distributions of facet remodeling and sclerosis/eburnation display any similarity. This suggests that while facet remodeling and sclerosis/eburnation may result from similar circumstances, facet osteophytes and pitting may be the product of different etiologies.

The mechanically induced nature of facet remodeling implies that it may potentially be one of the most sensitive indicators of lifestyle and load-bearing. In light of the known differences in lifestyle and the gendered division of labor at Ensay and Wharram Percy, statistically significant variations in the prevalence of facet remodeling between sites and sexes and in the lower segments of vertebral columns of individuals from Ensay suggest that this is indeed largely the case. Furthermore, given the origin of facet remodeling, a degree of accompanying sclerosis and eburnation might be expected. This appears to be particularly true in the Ensay sample, where the distribution of sclerosis/eburnation follows that of facet remodeling.

The formation of facet osteophytes varies significantly in frequency between sites, indicating that lifestyle may also affect osteophyte formation. In addition, facet osteophytes display a slightly different distribution in Ensay females, suggesting that biomechanical factors may be influential. In view of the ethnographic and historical knowledge of Ensay and Wharram Percy,

facet osteophytes may therefore be a useful indicator of nonspecific lifestyle-related stress and, to a lesser extent, load-bearing.

However, pitting displays strikingly similar distributions in both sexes from both sites, suggesting that even in Ensay females, its formation is largely due to the natural curvature and support functions of the spine. The lack of a statistically significant difference in the prevalence of pitting in the inter- or intrasite comparisons suggests that pitting cannot be specifically identified as either a lifestyle or occupation-related osseous modification.

Thus, contrary to the opinions of many researchers investigating skeletal osteoarthritis, the results presented here accord with those of Rothschild (1997). They indicate that the variety of observations hitherto described under the general headings of DJD or OA should not be considered as reflecting a single condition. Inconclusive results generated by other workers (e.g., Knüsel et al., 1997) may therefore in part result from the loss of several degrees of discrimination through combining observations in the analysis and presentation of results. Further systematic research needs to be carried out to determine the relationship between pitting, osteophyte formation, sclerosis/eburnation, and facet remodeling on the level of the individual. Nonetheless, in contrast to the debates over the etiology of OA, the biomechanical forces leading to facet remodeling may make it one of the most reliable indicators of load-bearing.

Bilateral asymmetry in osseous change down the spine

Facet remodeling, osteophytes, pitting, and eburnation display a degree of bilateral asymmetry for both sexes in the Wharram Percy and Ensay samples. The left side is generally dominant in the cervical region, and the right in the upper thoracic. Dominance in the lower thoracic and lumbar segments is less distinct. This pattern accords with the findings of Shore (1935), Stewart (1966), Merbs (1983), Kilgore (1984), and Bridges (1994), who found similar patterns of asymmetry of OA in the apophyseal facets of the spine and with the study by Wilkinson (1995) of asymmetry of the cervical unciate processes in the Ensay sample.

It therefore appears that the development of asymmetry has a basic patterning. It has been suggested that this results from the presence of the aorta, which travels down the left side of the spine in the upper thoracic region, inhibiting the formation of osteophytes on that side (Nathan, 1962). However, as Bridges (1994) pointed out, this would not affect the development of arthritis on the articular facets at the back of the spine. An alternative explanation is that the asymmetry of arthritis at these joints is related to stresses imposed on the vertebral column by the musculature associated with the arms (Nathan, 1962; Merbs, 1983; Bridges, 1994). The trapezius and rhomboid muscles that raise and lower the upper limb attach in part to the upper thoracic spine. Most people are right-handed and, as a result, more stress might be placed on the upper thoracic region, where asymmetry is most strongly marked (Bridges, 1994). Nonetheless, bilateral asymmetry in osseous change does not seem to be related to culturally defined gendered activity patterns.

CONCLUSIONS

The skeletally described sex differences in both samples correspond well with known anthropologically and historically described differences between sites and sexes in the level of activity-related stress on the spine. Overall, the Ensay sample is more highly stressed than that from Wharram Percy. Differences between males and females at Ensay can be identified as relating to different types of activities. Contrasts between males and females at Wharram Percy are less marked, suggesting broadly similar activities and lifestyles. It is possible to interpret the prevalence and distribution of osseous change down the spine by reference to the biomechanical effects of gendered activities known to have taken place at the two sites. In particular, osseous modifications in Ensay females may be understood with regard to the way that women on Ensay carried loads, using creels.

The impact of gender roles on the skeleton varies both qualitatively and quantitatively, according to both the general level of life-

style stress and the nature of the particular gendered activities in which individuals may be engaged on a regular basis. Differences in the distribution and prevalence of osseous change can be understood in terms of the interplay between natural and activity-induced stresses operating differently at particular locations on the spine. Unique activities or lifestyles may have distinct skeletal consequences, as morphologically different types of osseous change may also be etiologically different. However, a fine enough level of discrimination must be applied to the collection of data through the separate recording of morphologically and etiologically distinct osseous changes.

ACKNOWLEDGMENTS

Many thanks are due to Dr. Simon Mays of English Heritage, Prof. A.E.W. "Loma" Miles, Theya Molleson, and Robert Kruszynski of the Natural History Museum, London, for granting access to the skeletal remains. Dr. Mays and Prof. Miles also kindly provided unpublished data on the sexing, aging, and dating of the remains from Wharram Percy and Ensay. Dr. Mays was kind enough to comment on previous drafts of this paper. I also thank the anonymous reviewers for their thoughtful and useful comments. This research was supported by the British Academy as part of a doctoral thesis at the University of Cambridge, UK.

LITERATURE CITED

Adams MA, Hutton WC. 1980. The effect of posture on the role of the apophysial joints in resisting invertebral compressive forces. J Bone Joint Surg (Br) 62:358–363.

Angel JL. 1979. Osteoarthritis in prehistoric Turkey and medieval Byzantium. Henry Ford Hosp Med J 27: 38–43.

Arriaza BT. 1993. Seronegative spondylarthropathies and diffuse idiopathic skeletal hyperostosis in ancient northern Chile. Am J Phys Anthropol 91:263–278.

Arriaza BT, Merbs CF, Rothschild BM. 1993. Diffuse skeletal hyperostosis in meroitic Nubians from Semna South, Sudan. Am J Phys Anthropol 92:243–248.

Atkinson SJ. 1985. Variation in rates of age-related change in skeletal tissue in a Romano-British population. Unpublished Ph.D. dissertation. University of Durham.

Barnett JM. 1961. Synovial joints. London: Longmans.

Bell RD, Beresford MW. 1987. Wharram. A study of settlement on the Yorkshire Wolds, volume 3. Wharram Percy: the church of St. Martin. London: Society for Medieval Archaeology.

Bennett JM. 1987. Women in the medieval English countryside: gender and household in Brigstock before the plague. Oxford: Oxford University Press.

Bennike P. 1985. Paleopathology of Danish skeletons. A comparative study of demography, disease and injury. Copenhagen: Akademisk Forlag.

Beresford M, Hurst J. 1990. English Heritage book of Wharram Percy: deserted medieval village. London: Batsford.

Bridges PS. 1991. Degenerative joint disease in hunter-gatherers and agriculturalists from the southeastern United States. Am J Phys Anthropol 85:379–391.

Bridges PS. 1993. The effect of variation in methodology on the outcome of osteoarthritic studies. Int J Osteoarchaeol 3:289–295.

Bridges PS. 1994. Vertebral arthritis and physical activities in the prehistoric southeastern United States. Am J Phys Anthropol 93:83–93.

Brothwell DR. 1981. Digging up bones, 3rd ed. London: Oxford University Press/British Museum of Natural History.

Cameron AD. 1986. Go listen to the crofters: the Napier Commission and crofting a century ago. Stornoway: Acair.

Chapman FH. 1968. Osteophytosis in the vertebral column in a number of American Indian populations—a descriptive study in paleopathology. Unpublished Ph.D. dissertation. University of Indiana, Champaigne-Urbana, Indiana.

Chapman FH. 1972. Vertebral osteophytosis in prehistoric populations of central Mexico. Am J Phys Anthropol 36:31–38.

Currey HLF, editor. 1986. Mason and Currey's clinical rheumatology. Edinburgh: Churchill Livingstone.

Edynak GJ. 1976. Lifestyles from skeletal material: a medieval Yugoslav example. In: Giles E, Friedlaender JS, editors. The measures of man. Cambridge, MA: Peabody Museum Press. p 408–432.

Engel A. 1968. Osteoarthritis and body measurements. National Center for Health Statistics series 11.

Farfan HF. 1973. Mechanical disorders of the low back. Philadelphia: Lea and Febiger.

Fisher AGT. 1929. Chronic non-tuberculous arthritis. London.

Goldberg PJP. 1992. Women, work and life cycle in a medieval economy: women in York and Yorkshire c.1300–1520. Oxford: Clarendon Press.

Goranov I, Boev P, Kondova N, Cholakov S. 1983. Palaeopathological data for the spinal column diseases. Acta Morphol (Sofia) 4:57–63.

Hollander JL, McCarty DJ Jr, editors. 1972. Arthritis and allied conditions. Philadelphia: Lea and Febiger.

Howell DS. 1989. Etiopathogenesis of osteoarthritis. In: McCarty DJ, editor. Arthritis and allied conditions, 11th ed. Philadelphia: Lea and Febiger. p 1595–1604.

Jurmain R. 1977. Stress and the etiology of osteoarthritis. Am J Phys Anthropol 46:353–366.

Jurmain R. 1980. The pattern of involvement of appendicular degenerative joint disease. Am J Phys Anthropol 53:143–150.

Jurmain R. 1990. Paleoepidemiology of a central California prehistoric population from CA-ALA-329: II. Degenerative disease. Am J Phys Anthropol 83:83–94.

Kennedy KAR. 1989. Skeletal markers of occupational stress. In: Iscan MY, Kennedy KAR, editors. Reconstruction of life from the skeleton. New York: Alan R. Liss. p 129–160.

Kieser JA, Preston CB, Evans WG. 1983. Skeletal age at death: an evaluation of the Miles method of ageing. J Archaeol Sci 10:9–12.

Kilgore L. 1984. Degenerative joint disease in a medieval Nubian population. Unpublished Ph.D. dissertation. University of Colorado, Boulder, Colorado.

Knüsel CJ, Göggel S, Lucy D. 1997. Comparative degenerative joint disease of the vertebral column in the medieval monastic cemetery of the Gilbertine priory

of St. Andrew, Fishergate, York, England. Am J Phys Anthropol 103:481–495.
Kramar C, Lagier R, Baud CA. 1990. Rheumatic diseases in Neolithic and medieval populations of western Switzerland. Z Rheumatol 49:338–345.
Lovell NC. 1994. Spinal arthritis and physical stress at Bronze Age Harappa. Am J Phys Anthropol 93:149–164.
Maat GJR, Mastwijk RW, Van Der EA. 1995. Skeletal distribution of degenerative changes in vertebral osteophytosis, vertebral osteoarthritis and DISH. Int J Osteoarchaeol 5:289–298.
Macdonald D. 1978. Lewis. A history of the island. Edinburgh: G. Wright.
MacGregor AA. 1952. The Western Isles. London: Robert Hale Ltd.
Martin M. 1703. A description of the western islands of Scotland. London.
Mays S. 1996. Age-dependent cortical bone loss in a medieval population. Int J Osteoarchaeol 6:144–154.
Merbs CF. 1983. Patterns of activity-induced pathology in a Canadian Inuit population. Ottawa: Archaeological Survey of Canada. National Museum of Man, Mercury series 119.
Miles AEW. 1962. Assessment of the ages of a population of Anglo-Saxons from their dentitions. Proc R Soc Med 55:881–886.
Miles AEW. 1963. The dentition in the assessment of individual age in skeletal material. In: Brothwell DR, editor. Dental anthropology. London: Pergamon Press.
Miles AEW. 1989. An early Christian chapel and burial ground on the Isle of Ensay, Outer Hebrides, Scotland with a study of the skeletal remains. Oxford: British Archaeological Reports British series 212.
Miles AEW. 1996. Humeral impingement on the acromion in a Scottish island population of c.1600 AD. Int J Osteoarchaeol 6:259–288.
Miles AEW. No date. Humeral impingement on the acromion. London: Natural History Museum.
Molleson T. 1989. Seed preparation in the Mesolithic: the osteological evidence. Antiquity 63:356–362.
Molleson T. 1994. The eloquent bones of Abu Hureyra. Sci Am 271:70–75.
Murray WH. 1966. The Hebrides. London: Cox & Wyman.
Nathan H. 1962. Osteophytes of the vertebral column. J Bone Joint Surg (Am) 44:243–268.
Oliver J, Middleditch A. 1991. Functional anatomy of the spine. Oxford: Butterworth-Heinemann.
Ortner DJ, Putschar WGJ. 1981. Identification of pathological conditions in human skeletal remains. Washington, DC: Smithsonian Institution Press.
Peyron JG. 1986. Osteoarthritis. The epidemiologic viewpoint. Clin Orthop 213:13–19.
Pfeiffer BH. 1977. Local pieizoelectricity polarization of human cortical bone as a function of stress frequency. J Biomech 10:53–57.
Pinals RS. 1972. Traumatic arthritis and allied conditions. In: Hollander JL, McCarty DJ, editors. Arthritis and allied conditions. Philadelphia: Lea and Febiger. p 1391–1410.
Radin EL, Paul IL, Rose RM. 1972. Mechanical factors in osteoarthritis. Lancet 1:519–522.
Radin EL, Paul IL, Rose RM. 1980. Osteoarthrosis as a final common pathway. In: Nuki G, editor. The aetiopathogenesis of osteoarthrosis. Tunbridge Wells: Pittman Medical Publishing. p 84–89.
Rahtz P, Watts L. 1983. Wharram Percy: the memorial stones of the churchyard. York: Department of Archaeology, University of York in association with the Medieval Village Research Group.
Rogers J, Waldron T. 1995. A field guide to joint disease in archaeology. Chichester: Wiley.
Rogers J, Waldron T, Dieppe P, Watt I. 1987. Arthropathies in palaeopathology: the basis of classification according to most probable cause. J Archaeol Sci 14:179–193.
Rogers J, Watt I, Dieppe P. 1995. Paleopathology of spinal osteophytosis, vertebral ankylosis, ankylosing spondylitis, and vertebral hyperostosis. Ann Rheum Dis 44:113–120.
Rothschild BM. 1997. Porosity: a curiosity without diagnostic significance. Am J Phys Anthropol 104:529–533.
Rubin CT, McLeod KJ, Bain SD. 1990. Functional strains and cortical bone adaptation: epigenetic assurance of skeletal integrity. J Biomech 23:43–54.
Säger P. 1969. Spondylosis cervicalis. A pathological and osteoarchaeological study of osteochondrosis invertebralis cervicalis, arthrosis uncovertebralis and spondylarthrosis cervicalis. Copenhagen: Munksgaard.
Schaffler MB, Radin EL. 1992. Osteophytes and other bone changes in osteoarthrosis. In: Bálint G, Gömör B, Hodinka L, editors. Rheumatology, state of the art. Excerpta Medica. Amsterdam: Elsevier Science Publishers. p 198–201.
Schmorl G, Junghanns H. 1971. The human spine in health and disease, 2nd ed. New York: Grune and Stratton.
Schumacher HR, editor. 1988. Primer on the rheumatic diseases, 9th ed. Atlanta: Arthritis Foundation.
Shore LR. 1935. On osteoarthritis in the dorsal invertebral joints. Br J Surg 22:833–849.
Sinclair J, editor. 1794. The statistical account of Scotland. Edinburgh.
Stewart TD. 1947. Racial patterns in vertebral osteoarthritis. Am J Phys Anthropol 5:230–231.
Stewart TD. 1958. The rate of development of vertebral osteoarthritis in American whites and its significance in skeletal age identification. Leech 28:144–151.
Stewart TD. 1966. Some problems in human palaeopathology. In: Jarcho S, editor. Human palaeopathology. New Haven: Yale University Press. p 43–55.
Stewart TD. 1976. Identification by the skeletal structures. In: Camps FE, editor. Gradwohl's legal medicine, 3rd ed. Bristol: Wright. p 109–135.
Stewart TD. 1979. Patterning of skeletal pathologies and epidemiology. In: Laughlin WS, Harper AB, editors. The first Americans: origins, affinities, and adaptations. New York: Gustav Fischer. p 257–274.
Swedborg I. 1974. Degenerative changes of the human spine—a study on dried macerated skeletons. Stockholm: Karolinska Institutet.
Trinkaus E. 1975. Squatting among the Neanderthals: a problem in the behavioural interpretation of skeletal morphology. J Archaeol Sci 2:327–351.
Tyrrell AR, Reilly T, Troup JDG. 1985. Circadian variation in stature and the effects of spinal loading. Spine 10:161–164.
Waldron T. 1991. The prevalence of and the relationship between some spinal diseases in a human skeletal population from London. Int J Osteoarchaeol 1:103–110.
Walker PL, Hollimon S. 1989. Changes in osteoarthritis associated with the development of a maritime economy among southern California Indians. Int J Anthropol 4:171–183.
Wells C. 1964. Bones, bodies and disease. London: Thames and Hudson.
Wilkinson R. 1995. An examination and comparison of the human uncinate processes with regard to age, sex and occupation. Unpublished B.Sc. dissertation. Roehampton Institute. University of Surrey, London.
Yang KH, King AI. 1984. Mechanism of facet load transmission as a hypothesis for low-back pain. Spine 9:557–565.